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# ON THE ORIGIN OF CERTAIN SILICEOUS ROCKS.

## I. NOTES ON ARKANSAS NOVACULITE.

An examination of the residues of specimens representing both the Ouachita and Arkansas (commercial) types of novaculite confirms Griswold's observations and conclusions made on thin sections. Ground in an agate or porcelain mortar, the greater part of the rock is easily reduced to a fine slime that readily floats away in water. A considerable portion, however, consists of granules which, though made up of fine grains, require considerable rubbing to reduce them to slime. Even when, in the final stages of the grinding, a soft pestle is employed to avoid breaking up the grains of quartz and other minerals, a considerable number of the aggregated granules remain, thus showing a strong cohesion of the constituent grains.

The amount of quartz in simple grains that can be positively identified by the polarization colors is not large, and for the most part is not distinctly detrital. Such grains are frequently enclosed in the composite ones or have composite silica adhering to them, and often appear to be more completely developed individuals of the aggregated grains. In many cases, however, they appear to be detrital grains with adherent secondary silica. Unmistakable detrital grains are represented by numerous zircons and rare fragments of tourmaline and garnet.[1] These are exceedingly fine, and both in character and amount seem to confirm Griswold's conclusion that the deposit took place in still and comparatively deep water into which only a small amount of very fine detritus would be floated.

The great bulk of the silica of these rocks appears to be secondary, and to account for its peculiarities the replacement hypothesis of Rutley seems to offer less difficulty than that of an originally siliceous sediment of Griswold. The latter must either have been chemical, which Griswold expressly rejects, and apparently very properly, or composed of very fine granular quartz. In the latter case the granules, however fine, have been still further granulated, a species of metamorphism which has apparently not been observed elsewhere, and which is difficult to conceive. The metamorphism, if there had been any, would rather be expected to be in the direction of larger and well-defined grains of quartz, such as were noted in some of Griswold's slides (No. 14).[1] The latter slide seems to be a case of replacement according to Rutley's hypothesis "caught in the act." It may be suspected that in a larger suite, especially of non-commercial stones, other such cases might be found.

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[1] Wichmann found garnets in the novaculites of the Marquette, Mich., district in 1879. Q. J. Geol Soc., Vol. XXXV, 1879, pp. 156–164, J. C. Branner.

Griswold's explanation of the cavities seems also to point in the direction of a replacement, and can be reconciled with Rutley's hypothesis on the supposition, which does not seem difficult, that part of the original calcareous sediment may have crystallized (not necessarily as dolomite) and thus have offered greater resistance to the replacement.

The description of the beds also is suggestive of original limestones with cherty layers and nodules. Two of the specimens sent appear to me to represent such cherts, though I should not call them metamorphosed.

The question of the state of the silica seems to me to be one of quite secondary importance, as in the case of silicified wood replacement silica is met with in all states, and often with an appearance of a passage to the state of quartz after the replacement.

Viewing the question from a distance, and on a very insufficient basis, it seems probable that if Mr. Griswold had taken into consideration the hypothesis of a replacement of calcareous sediments, he would, perhaps, have found much more in its favor than either Rutley or I could see.

For the study of crucial points, "non-commercial" rock will probably be often better than the "commercial," and the preparation and examination of residues more rapid and satisfactory than that of microscopic sections.

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[1] Whetstones and the Novaculites of Arkansas. By L. S. GRISWOLD. Ann. Rep. Geol. Surv. Ark. for 1890, III, p. 128.

ORVILLE A. DERBY.

SAO PAULO, Brazil, April 6, 1898.

## II. ON THE ORIGIN OF NOVACULITES AND RELATED ROCKS.

The preceding part of this paper was recently received by me from Professor O. A. Derby as embodying the results of his examination of novaculites by a method hitherto not employed with those rocks. It should be added that in a former letter he sent me the results of a study by this same method of an impure cherty Carboniferous limestone from Tieté, São Paulo. In this limestone he found by crushing and washing, rolled quartz, zircon, rutile, garnet, tourmaline, etc.

These notes I have taken the liberty to publish without consulting Professor Derby in order that the results of his work may become available for others who may study this interesting and important group of rocks.

It is remarkable that so many different views have been held regarding the origin of novaculites and of the closely related highly siliceous rocks known as jaspilites and sometimes as jaspers, siliceous shales, etc.

The following theories have been advanced to explain the origin of these rocks:

Foster and Whitney seem to have regarded the jaspers of Michigan[1] as segregations of eruptive origin. Owen considered the Arkansas novaculites as metamorphosed sandstone.[2]

Kimball believed the Marquette iron ores and their associated jaspers to be metamorphic rocks of sedimentary origin, presumably mechanical.[3]

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[1] Geology and Topography of the Lake Superior Land District. Pt. II. The Iron Region, pp. 67–69, 1851.

[2] Second Geol. Surv. Ark., pp. 23, 25, 1860.

[3] Am. Jour. Sci., Vol. XXXIX, p. 303, 1865.

Crosby thinks some of the jaspers and quartzites are the siliceous oozes of the deep sea, that is, that they are of organic origin.[1]

Wadsworth at first believed in an eruptive origin for the jaspilites.[2] This view he modified later.

Julien believes in the mechanical sedimentary origin of the jasper iron ores of the Marquette region, and it is to be presumed that he considers the jaspers mechanical sediments also.[3]

Irving concluded that the jaspers were formed by silica replacing dolomite or calcite.[4]

Reyer thinks the sediments associated with the iron ores of Michigan are derived partly from decomposed igneous rocks and partly from organic remains.[5]

Branner has suggested that the compact novaculites may be metamorphosed cherts.[6]

Comstock considered many of the Arkansas novaculites to be hot water deposits.[7]

Julien thinks amorphous silica is produced by marine organisms, or by precipitation from solutions.[8]

Griswold is of the opinion that novaculites are simply metamorphosed, fine grained, mechanical sediments.[9]

N. H. and H. V. Winchell believe in the theory of chemical precipitation for the jaspilites.[10]

James E. Mills is of the opinion that certain quartzites of the

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[1] Proc. Bost. Soc. Nat. Hist., Vol. XX, pp. 167–168, 1878–1880.

[2] Bull. Mus. Comp. Zool., Vol. VII, p. 30, 1880; Proc. Bost. Soc. Nat. Hist., Vol. XX, pp. 477–478, 1878–1880; Bull. Mus. Comp. Zool. Harvard Col., Geol. Ser. I, Vol. XVI, pp. 331–565, 1884.

[3] Genesis of the Crystalline Iron Ores. By A. A. JULIEN. Eng. Mining Jour., Vol. XXVII, pp. 81–83, 1884.

[4] Am. Jour. Sci., Vol. XXXII, p. 255, 1886.

[5] Geologie der amerikanischen Eisenlagerstätten. E. REYER. Oest. Zeitsch. f. Berg. u. Huttenwesen, XXXV, Nos. 10 and 11, 1887.

[6] Ann. Rep. Geol. Surv. Ark., Vol. I, p. 49, footnote, 1888.

[7] Ann. Rep. Geol. Surv. Ark., Vol. I, pp. 95, 129, 1888.

[8] Proc. A. A. A. S., Vol. XXVII, pp. 311–340, 1889.

[9] Ann. Rep. Geol. Surv. Ark., Vol. III, pp. 164, 194, 1890.

[10] The Iron Ores of Minnesota. By N. H. and H. V. WINCHELL. Minneapolis, 1891, p. 74.

Sierras, in California, are replacements of clays by silica,[1] and that others are possibly replacements of limestone by silica.

Wadsworth came to believe in their sedimentary origin.[2]

Rutley in a review of the subject reached the conclusion that the novaculites were replacements by silica of dolomites or of dolomitic limestones.[3]

Hinde expressed the opinion on the occasion of the reading of Rutley's paper that these rocks were of organic origin.[4]

Lawson thinks the "radiolarian cherts," that is, the jaspers of the coast ranges of California, are local deposits chemically precipitated from submarine siliceous springs.[5]

Branner thinks the jaspers are of organic origin.[6]

Van Hise in speaking of certain jaspers of the Marquette district says: "It appears highly probable that dynamic action transformed the ferruginous chert into the jasper."[7]

Derby's views, that novaculites are replacements of limestones by silica, are given in the first part of the present paper.

Fairbanks has concluded that the Tertiary siliceous shales of the coast ranges of California are derived from diatomaceous beds.[8]

Doubtless many other expressions of views regarding the origin of these siliceous rocks might readily be found, but these are enough to show that there has been the widest possible difference of opinions on the subject.

We have then the following theories, that the novaculites, jaspilites, jaspers, etc., are:

1. Mechanical silts.
2. Organic silts.

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[1] Bull. Geol. Soc. Am., Vol. III, pp. 421–422, 440, 1892.

[2] M. E. WADSWORTH, Rep. State Geol. for 1891–2. State Board of Geol. Surv. (of Michigan) for 1891–2. Lansing, 1893, pp. 75–155, dated March 1892.

[3] Quart. Jour. Geol. Soc., Vol. L, p. 386, 1894.

[4] Quart. Jour. Geol. Soc., Vol. L, p. 391–392, 1894.

[5] 15th Ann. Rep. U. S. G. S., pp. 425–426, 1895.

[6] Trans. Amer. Soc. C. E., Vol. XXXIX, p. 58. Read Nov. 17, 1897.

[7] Monog. U. S. G. S., Vol. XXVIII, p. 372, 1897.

[8] San Luis Obispo folio, U. S. G. S. (MSS.).

3. Chemical precipitates.
4. Igneous deposits.
5. Replacements of clays.
6. Replacements of limestones.
7. Replacements of dolomites.

The most comprehensive discussions of this subject are those of Griswold and of Rutley. But these writers do not agree in regard to the origin of the rocks, the former believing them to be fine sediments, the latter believing them to be replacements of dolomites or limestones.

My own opinions have not been based upon such microscopic study as either Griswold or Rutley devoted to this work, and for that reason were not worthy of special consideration. Since I began to study the geology of the coast ranges of California, however, I have, I believe, seen much that throws light upon the origin of the novaculites and similar rocks.

These observations embrace those upon geological structure, gross and microscopic structure, composition and geological relations, and lead me to believe that the white siliceous shales so characteristic of the Tertiary, the jaspers and the diatomaceous beds are only various phases of the same thing.

I am glad to say that Dr. H. W. Fairbanks, whose acquaintance with the coast range geology makes his opinion especially valuable, expresses similar views on this subject. Dr. Fairbanks, however, has undertaken a thorough study of this subject from which important results may be expected.

J. C. BRANNER.

STANFORD UNIVERSITY, CALIFORNIA.
June 4, 1898.